ILLINOIS NATURAL HISTORY SURVEY

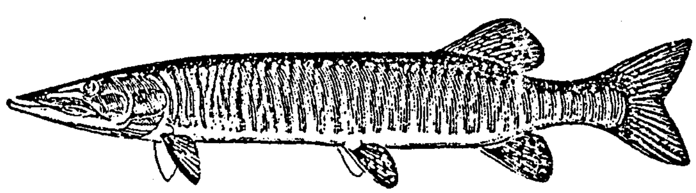
Evaluation of Muskellunge and Tiger Muskellunge Stocking Program

Project F-113-R-1

Annual Report to
Illinois Department of Conservation

Center for Aquatic Ecology

T. A. Szendrey, D. F. Clapp, D. P. Philipp, and D. H. Wahl



September 1992

Aquatic Ecology Technical Report 92/12

EVALUATION OF MUSKELLUNGE AND TIGER MUSKELLUNGE STOCKING PROGRAM

July 1, 1991 through June 30, 1992

T.A. Szendrey, D.F. Clapp, D.P. Philipp and D.H. Wahl

Center for Aquatic Ecology, Illinois Natural History Survey

Submitted to
Division of Fisheries
Illinois Department of Conservation
Federal Aid Project F-113-R

David H. Wahl
Principal Investigator

David P. Philipp
Director
Center for Aquatic Ecology

August 1992

This study was conducted under a memorandum of understanding between the Illinois Department of Conservation and the Board of Trustees of the University of Illinois. The research was performed by the Illinois Natural History Survey, a division of the Illinois Department of Energy and Natural Resources. The project was supported by funds made available through the Federal Aid in Sport Fish Restoration Act and administered by the Illinois Department of Conservation. The form and content of this report and the interpretations of the data are the responsibility of the University of Illinois and the Illinois Natural History Survey and not the Illinois Department of Conservation.

Table of Contents

Study 101. **<u>Evaluation of muskellunge and tiger muskellunge stocking program.</u>**

STUDY 101. <u>Evaluation of muskellunge and tiger muskellunge stocking program.</u>

JOB 101.1 <u>Size-specific survival of muskellunge and tiger muskellunge.</u>

OBJECTIVE: To compare survival of various sizes of muskellunge and tiger muskellunge stocked in Illinois impoundments.

INTRODUCTION: Stocking is a popular management tool to provide sport fishing opportunities and to supplement existing sport fish populations (Keith 1986). The success of fish stocking programs is largely dependant upon the ensuing survival rates. Stockings of esocid fingerlings have displayed extremely variable survival rates (Wahl and Stein 1989; Stein et al 1981; Johnson 1982). The sizes to which esocids must be reared to attain acceptable rates of survival is largely dependant upon system specific characteristics such as forage species abundance and size, predator density and size distribution, and thermal regime. Survival of esocid fingerlings in impoundments has been shown to be largely dependant upon predation by resident largemouth bass (Stein et al. 1981) and the composition and abundance of forage fishes (Wahl and Stein 1988). Sizes to which esocids must be reared will vary according to the predator population and forage base of a specific system. The success of various size stockings need to be correlated with these factors to develop guidelines for impoundment stockings. These results will be used to improve and test a bioeconomic model developed by Wahl and Stein (1990) to compare the factors influencing survival of various sizes of esocids as a function of cost of rearing. In this job, we evaluate the relative survival of 4, 8 and 10 inch muskellunge and tiger muskellunge with impoundment stockings, and assess the effects of predator populations and prey resources on survival. These data will be used to help develop guidelines for future esocid stockings in Illinois.

METHODS: Lake George (Rock Island Co.) was stocked with 4, 8 and 10 inch muskellunge and Paradise Lake (Coles Co.) was stocked with 4, 8 and 10 inch tiger muskellunge. Numbers of fish stocked varied by size and species of esocid (Table 1). All fish were reared intensively at the Jake Wolf Memorial fish hatchery in Manito, Illinois, by the Illinois Department of Conservation. Unique fin clips were given to each size group of fish. A sample of each esocid size group was measured (nearest mm) and weighed (nearest g) prior to stocking (Table 1). Fish were tempered to within 2°C of lake temperature before stocking to avoid thermally stressing the fish (Mather and Wahl 1989). A sub-sample of each stocked group was held in three predator-free cages (N=15/cage) for 48 hours to monitor mortality associated with stress due to transport and stocking. Temperature and dissolved oxygen measurements were recorded on each sampling date in order to determine their influence on survival rates.

Predation by largemouth bass was determined by examining contents of largemouth bass stomachs with clear acrylic tubes (Van Den Avyle and Roussel 1980), and extracting any esocids. Largemouth bass were sampled by electrofishing the entire perimeter of each lake the first three nights after stocking, then once a week thereafter until no more esocids were collected from largemouth bass. Largemouth bass were marked to determine population estimates. The number of esocids collected from largemouth bass stomachs on each date was combined with largemouth bass population estimates to compute the total number of each esocid group eaten daily (Wahl and Stein 1989). These values were then summed to compute total predatory mortality.

Population estimates (Schnabel mark-recapture) and catch-per-unit-effort for muskellunge and tiger muskellunge were computed in the fall and spring to determine survival rates. The entire perimeter of each lake was sampled at weekly intervals by electrofishing. All esocids collected were given a caudal fin clip for mark-recapture population estimates of various sizes of stocked esocids.

RESULTS: Survival rates of stocked fish through fall revealed no survival for tiger muskellunge or muskellunge of the 4 inch size classes (Table 2). Four inch tiger muskellunge in Paradise Lake were not collected beyond the first week after stocking (Table 3), and catch of 4 inch muskellunge in Lake George ceased after the second week (Table 4).

In Paradise Lake, catch-per-unit-effort (CPUE) for 8 inch tiger muskellunge was low throughout fall sampling (Table 3), and survival estimates were not attainable. Ten inch fish stocked in the winter displayed relatively high CPUE values throughout spring sampling, and a spring mark-recapture population estimate showed good survival (27%).

Fall and spring electrofishing collections in Lake George showed consistent, although low, CPUE values for 8 and 10 inch muskellunge (Table 4). Insufficient numbers of recaptures were obtained in the fall to compute population estimates. Spring mark-recapture population estimates, however, were completed and showed low survival for 8 inch fish (1%) and slightly higher survival for the 10 inch size group (3%). For both taxa, survival was directly related to size of fish stocked (Table 2).

Numbers of esocids recovered from largemouth bass stomachs were combined with largemouth bass population estimates (Table 5) to estimate numbers of each esocid lost to predation. Largemouth bass predation accounted for nearly all of the mortality of four inch muskellunge in Lake George (Table 6). Losses to predation were substantially lower for the larger size groups of stocked fish. These estimates were hampered by lower catch rates of largemouth bass than in previous years and the winter stocking of some groups of fish. Winter stocking was required because fish to be stocked had been treated for diseases and were not cleared for stocking by the FDA until it was too late. These late stockings precluded sampling for largemouth bass.

In Lake George, 15% mortality of 4 inch fish was observed in predator-free cages 48 hours after stocking, indicating some affect of stocking stress. This mortality was likely due to stress from transport since fish from all stockings were acclimated to within 2°C of lake temperature prior to stocking. Eight inch muskellunge suffered 38% mortality in cages after 48 hours. These fish had noticeable tail damage when stocked, and soon after developed a mucus coating on the fins and most of the body. The ten inch fish had low stocking mortality (4%) as observed in predator-free cages. In contrast, no mortalities were observed in cages for three sizes of tiger muskellunge stocked in Paradise Lake.

We also continued to sample fish stocked in 1990 during both fall and spring collections. Sample sizes were small but confirmed earlier findings of essentially zero survival of 4 inch size groups, but better survival of larger size groups. In Pierce Lake, one 8 inch muskellunge and two 6 inch muskellunge from the 1990 stockings were captured during fall 1991 and spring 1992. No fish from the 10 inch size groups were collected. In addition, no tiger muskellunge of any size group were collected in extensive sampling. These results are somewhat surprising and should be monitored further in subsequent years of sampling.

RECOMMENDATIONS: Stockings of 4, 8 and 10 inch muskellunge should be repeated in 1992 in order to further evaluate the effects of size at stocking on survival and growth rates of esocids. These stockings are particularly important given the unusual stocking times caused by problems with FDA clearance. Results from the 1990 and 1991 stockings indicate that survival of fish less than 10 inches is poor, and no survival has been observed for stockings of fish less than 8 inches. In 1992, the muskellunge lake should be switched with those used in Job 101.2 in order to eliminate individual lake effects. In addition, sampling of fish stocked in 1990, 1991 and 1992 should continue in order to monitor the effect of size at stocking on survival and growth rates through the second and third years. In subsequent segments, we will also begin to incorporate data collected in this job into the esocid bioeconomic model. Simulations from this improved model will be useful in determining trade-offs between costs of rearing and size at stocking for individual impoundment characteristics. These simulations will then be used to make management recommendations regarding stocking of esocids in lakes throughout Illinois.

JOB 101.2 Effect of rearing technique on esocid survival

OBJECTIVE: To compare survival of minnow and pellet reared muskellunge and tiger muskellunge in impoundments.

INTRODUCTION: In addition to size at stocking, another factor which hatcheries can control which may potentially impact stocking success is rearing method. Extensive rearing of esocid fingerlings on minnows has been utilized for most stocking programs, however intensive rearing on pellets has been found to be a less expensive alternative (Klingbiel 1986). However, the survival and behavioral characteristics of esocids reared on minnows and dry diets should be evaluated before the implementation of large-scale use of artificial diets (Hanson et al 1986; Carline et al 1986). Differential susceptibility to predation and conversion to available prey sources may greatly influence the survival and growth rates of fingerling esocids reared by different methods. In this job, we compare survival and growth rates of minnow and pellet reared muskellunge and tiger muskellunge and evaluate potential mechanisms causing observed differences in growth and survival.

METHODS: Equal numbers and similar sizes (200 mm) of minnow and pellet reared muskellunge and tiger muskellunge were stocked simultaneously into reservoirs in Illinois (Table 1). These esocids are of a size that typically show intermediate survival, and have the potential to be greatly affected by rearing method. Muskellunge were stocked in Pierce Lake (Winnebago Co.) and tiger muskellunge in Paris-Twin Lake (Edgar Co.)

All fish were reared intensively at the Jake Wolf Memorial fish hatchery in Manito, Illinois by the Illinois Department of Conservation. Pellet reared esocids were marked with oxytetracycline, whereas minnow reared fish were not. Oxytetracycline is incorporated into calcium deposits and will fluoresce under ultraviolet light (Wahl and Stein 1987). Incorporating oxytetracycline into the food allowed esocids recovered from largemouth bass stomachs to be distinguished by rearing method. Minnow and pellet reared fish of both species were graded to match sizes. Minnow and pellet reared esocids received unique fin clips prior to stocking which has been found to be an effective method of marking stocked esocids (McNeil and Crossman 1971). A sample of each esocid rearing type was measured (nearest mm) and weighed (nearest g) prior to stocking (Table 1). Fish were tempered to within 2°C of lake temperature before stocking to avoid thermally stressing the fish (Mather and Wahl 1989). A sub-sample of each stocked group was held in three predator-free cages (N=15/cage) for 48 hours to monitor mortality associated with stress due to transport and stocking.

Susceptibility to predation by largemouth bass was determined as in Job 101.1. The number of minnow and pellet reared fish collected from largemouth bass stomachs on each date was combined with largemouth bass population estimates to compute the total number of each rearing type eaten daily. These values were then summed to compute total predatory mortality. Temperature and dissolved oxygen measurements were recorded on each sampling date in order to determine their influence on survival rates.

Population estimates and catch-per-unit-effort for minnow and pellet reared muskellunge and tiger muskellunge were computed in the fall and spring to determine survival rates. The entire perimeter of each lake was sampled at weekly intervals by electrofishing. All esocids collected were given a caudal fin clip for mark-recapture population estimates of minnow and pellet reared fish.

RESULTS: Number of tiger muskellunge recovered from largemouth bass stomachs indicated higher susceptibility to predation for pellet reared than minnow reared fish. Estimates of predatory losses following stocking of muskellunge in Pierce Lake were not possible because fish were not available until January, and ice cover prevented predator sampling. In Paris-Twin Lake, more pellet reared (N=9) than minnow reared (N=3) tiger muskellunge were recovered from largemouth bass stomachs. On each sampling date, more pellet reared fish were recovered from largemouth bass stomachs than minnow reared fish (Fig 1). When numbers of tiger muskellunge collected from largemouth bass stomachs on each date were combined with the largemouth bass population estimate in Paris-Twin Lake (Table 5), estimated predation was over four times higher on pellet reared than minnow reared tiger muskellunge (Table 6). These results, combined with similar results from 1990 (Fig. 2), suggest that rearing technique has a strong influence on relative predation rates of minnow and pellet reared esocids in impoundments, and thus is an important factor affecting survival.

Catch rates were low for tiger muskellunge in Paris-Twin Lake during fall and none were sampled past the seventh week after stocking (Table 7). Recaptures of pellet and minnow reared tiger muskellunge were too few to compute population estimates. Based on catch-per-unit-effort (CPUE), survival was initially higher for minnow reared than for pellet reared fish (Table 7).

Muskellunge in Pierce Lake were sampled as soon as ice cover disappeared, and electrofishing mark-recapture population estimates in spring revealed that survival of minnow reared fish (46%) was more than double that of pellet reared fish (24%). CPUE estimates confirmed these results as catch rates of minnow reared fish through spring were consistently higher (3 to 4 times) than pellet reared fish (Table 8).

We also continued to sample minnow and pellet reared esocids from stockings in 1990. Catch of minnow reared tiger muskellunge from the 1990 stocking in Paradise Lake was low but consistent (0.5/hr) throughout fall 1991 sampling. Electrofishing during spring 1992 did not capture any of these fish. No pellet reared fish were captured during these same time periods. In contrast, no subsequent catches were recorded of minnow or pellet reared muskellunge from the 1990 stocking in Lake George despite extensive sampling.

No mortality was observed in cages for 48 hours following stocking of tiger muskellunge, indicating no effect of transport or stocking stress on survival rates. Ice cover prevented estimates of post-stocking mortality on Pierce Lake.

RECOMMENDATIONS: Stockings of minnow and pellet reared tiger muskellunge should be repeated in 1992. This additional stocking is required to increase sample sizes for comparison of survival and vulnerability to predation between esocids reared by the two methods. Results from 1990 and 1991 stockings suggest rearing method may play an important role in determining esocid survival in impoundments. Predation by largemouth bass appears to be a major component of differential survival rates of minnow and pellet reared fish. Sampling of fish stocked in 1990, 1991 and 1992 should continue in order to monitor the effect of rearing method on survival and growth rates through the second and third years.

In subsequent segments, we will begin to examine differential survival of extensive versus intensively reared esocids. Data collected thus far suggest rearing technique can have a profound effect on esocid survival. It is likely that pond versus trough reared fish will also have substantially different survival rates. In order to determine the relative merits of pond versus trough reared fish it will be critical to have good estimates of relative survival between the two groups. Evaluation of the mechanisms determining differential survival, such as the role of predation mortality, will assist in developing system-specific stocking strategies for esocids reared by different techniques.

JOB 101.3 Laboratory and pond experiments.

OBJECTIVE: To evaluate growth and survival rates of various sizes, minnow versus pellet reared, and genetic stocks of esocids in laboratory and pond experiments.

INTRODUCTION: Pond and laboratory experiments have been used often to determine the mechanisms that cause differences observed in field studies (Wahl and Stein 1989, Werner et al. 1983, Savino and Stein 1982). In comparing survival of muskellunge, tiger muskellunge and northern pike, Wahl and Stein (1989) used both experimental ponds and laboratory pools to compare vulnerability of esocids to largemouth bass predation. These experiments were extremely useful in evaluating mechanisms of differential survival. Differences in susceptibility to predation among pellet and forage reared esocids may have dramatic influences on survival. In this job, we employ the use of experimental ponds and laboratory pools to examine the susceptibility to largemouth bass predation and habitat use of minnow and pellet reared muskellunge and tiger muskellunge.

METHODS: Susceptibility of intensively reared minnow and pellet fed tiger muskellunge to predation by largemouth bass was examined with pond (.04 ha) experiments. Tiger muskellunge reared intensively at the Jake Wolf hatchery were transferred to the Sam Parr Biological Station in Kinmundy, Illinois. Half of similar sized fish were reared on pellets and the other half were reared on minnows for at least four weeks prior to stocking. Pellet reared fish were marked with oxytetracycline and minnow and pellet reared fish received distinguishing fin clips. Experiments were conducted using 7 treatment and 3 control ponds. Pellet (N=25) and minnow (N=25) reared fish were added to each of 10 ponds. Treatment ponds also contained largemouth bass (N=6) and were used to examine relative predation rates on minnow and pellet reared fish. Control ponds did not contain largemouth bass and were used to monitor natural mortality. Temperature, dissolved oxygen and secchi depth were monitored daily after introduction of tiger muskellunge. All ponds were seined on days 1, 3 and 6 after stocking and tiger muskellunge were extracted from largemouth bass stomachs to compare losses to predation between rearing types. Numbers of minnow and pellet reared tiger muskellunge seined from each pond on each sample date will be used to evaluate survival through time. All ponds were drained on day 6 to determine tiger muskellunge survival rates.

RESULTS: Pond experiments with tiger muskellunge (mean length = 169 mm, mean weight = 20.4 g for pellet; mean length = 166 mm, mean weight = 20.7 g for minnow) showed mean survival to be similar based on seining during the experiments. Final survival in each of the ponds were compared with survival data from identical tiger muskellunge pond experiments conducted in 1990. Data from the two years were combined after testing for homogeneity of survival data between years in both experimental and control ponds (homogeneity X^2, experimental ponds, $p > .05$; control ponds, $p > .20$). Mean survival, after incorporating natural mortality from control ponds, was nearly identical for minnow and pellet reared fish (Fig 3). Survival of minnow and pellet reared tiger muskellunge in ponds was then examined by comparing differences in survival between control ponds and experimental ponds. Control ponds were used to monitor natural mortality, whereas experimental ponds determined predation mortality. By comparing differences in survival, we examined the affect of largemouth bass predation alone. Susceptibility to largemouth bass predation did not differ between minnow and pellet reared tiger muskellunge in these pond experiments (normal deviate, $p = .92$). Identical analysis of data from muskellunge pond experiments conducted in 1990 found similar survival rates (Fig 4) as with previous experiments, and also found that susceptibility to predation did not differ between minnow and pellet reared fish (normal deviate, $p = .84$). Thus, pond experiments did not show the same difference in susceptibility to predation as observed in reservoir studies. However, inherent limitations such as size of the ponds and lack of a habitat gradient likely affected these results. Because of these limitations, we believe reservoir results more accurately reflect the actual importance of predation in determining survival of stocked esocids.

Comparison of tiger muskellunge recovered from largemouth bass stomachs in pond experiments showed similar patterns as seine and survival data. Nearly equal numbers of pellet (N=11) and minnow (N=13) reared tiger muskellunge were eaten by largemouth bass in all ponds combined. When combined with largemouth bass predation data from 1990 tiger muskellunge pond experiments, numbers of pellet (N=48) and minnow (N=37) reared tiger muskellunge recovered where not significantly different (chi-square, $p > .20$). For additional comparison, total numbers of tiger muskellunge and muskellunge consumed by largemouth bass in individual pond experiments were estimated by summing numbers of fish eaten on each sampling date as in reservoir studies. Percent survival based on these data were not different for pond experiments with either tiger muskellunge during both years (paired t-test, $p = .18$) or for experiments with muskellunge ($p > .05$).

RECOMMENDATIONS: Additional laboratory experiments should be conducted to evaluate mechanisms for differential predation observed in the field. These experiments will examine foraging behavior of minnow and pellet reared fish, and will hopefully elucidate behaviors affecting differential vulnerability to largemouth bass predation in reservoirs. In addition, pond experiments should be conducted to examine survival of intensive versus extensively reared esocids as influenced by largemouth bass predation. Pond experiments should also be conducted to examine performance of different muskellunge stocks, and to compare this with laboratory findings which examined growth and food consumption of various muskellunge stocks.

JOB 101.4 <u>Growth and food habits of muskellunge and tiger muskellunge</u>

OBJECTIVE: To determine the effect of stocking size and rearing technique on growth rates and food habits of muskellunge and tiger muskellunge.

INTRODUCTION: The relative success of muskellunge and tiger muskellunge in utilizing prey resources in impoundments after introduction can play a large role in the overall success of a particular stocking. Differences in conversion to available prey sources in the field can significantly influence survival and growth rates (Wahl and Stein 1988 ; Tomcko et al 1984). These differences are primarily the result of foraging efficiency of the fish and characteristics of the individual prey species. Gillen et al. (1981) examined the effect of the diet history (minnow vs pellet fed) of tiger muskellunge on foraging success, and found pellet reared fish to require longer capture times and more strikes per capture than minnow reared fish. These differences may be attributable to behavioral differences between the two rearing methods. The availability of adequate sizes of forage fish to various sizes of stocked esocids can also influence survival. In this job, we examine the effect of rearing method and size at stocking on the prey utilization and growth rates of muskellunge and tiger muskellunge in impoundments.

METHODS: Each group of esocids stocked were sub-sampled for length (nearest mm) and weight (nearest g) prior to stocking (Table 1). Esocids were then collected at bi-weekly intervals by electrofishing the entire perimeter of each impoundment. Esocids were measured and weighed at each collection date to determine relative growth rates of minnow and pellet reared fish and of various sizes of stocked esocids. Stomach contents of all esocids collected were removed by stomach flushing (Foster 1977) to determine food habits and to examine differences in diet conversion between minnow and pellet reared esocids.

Five stations were seined with 75 foot hauls at bi-weekly intervals to determine inshore species composition, densities and size distribution of prey fishes available in each impoundment. Prey were identified to species and counted. These data will be used to evaluate the role of forage base in affecting growth and survival of stocked esocids.

RESULTS: Growth and food habits data were collected during fall and spring sampling collections after stockings of muskellunge and tiger muskellunge. Growth and food habits data was obtained from 8 and 10 inch tiger muskellunge in Paradise Lake. Data was not available for 4 inch fish because of their absence from sampling collections. Although sample sizes were low, eight inch tiger muskellunge displayed good growth in both length and weight through week 35 (Table 9). Food habits data showed a high percentage of fish containing food, with gizzard shad being the dominant prey item (Table 10). Gizzard shad were the most important prey even though seine collections found bluegill and other potential prey species to be abundant. These findings are consistent with those obtained from previous stockings in Paradise Lake, demonstrating the importance of gizzard shad as a food source for esocids in impoundments in Illinois. As in 1991, supplementary electrofishing samples have shown gizzard shad to be exceedingly abundant, with large numbers of appropriately sized gizzard shad available as forage.

Mean lengths and weights during spring of 10 inch tiger muskellunge in Paradise Lake showed small increases in length (Table 9), although fish were not sampled for as long a period of time. Additional sampling of these fish will be conducted during summer and fall. Analysis of food habits found a high proportion of fish containing prey items, with gizzard shad representing all of the identifiable prey (Table 10).

Growth and food habits data was also collected from muskellunge stocked in Lake George. Data was not attainable for 4 inch muskellunge due to rapid mortality rates. Muskellunge of the 8 and 10 inch sizes in Lake George showed moderate growth in length and weight through fall and spring (Table 11). Seining collections showed prey species to be numerous and varied, with cyprinids and centrarchids in highest abundance. Food habits analysis of muskellunge during fall and spring found cyprinids and *Lepomis* spp. to be the most heavily utilized prey items. The proportion of fish with food was higher in late fall and spring than at other times of the year (Table 12).

We also compared growth and food habits of pellet and minnow reared tiger muskellunge stocked in Paris-Twin Lake. Minnow reared tiger muskellunge appeared to grow slightly faster in length than pellet reared fish, although growth for both groups appeared to be poor (Table 13). In addition, only minnow reared fish were successful at capturing prey, based on food habits data (Table 14). Analysis of growth and food habits was limited, however, because catch of both rearing types ceased after 7 weeks. Seine samples in Paris-Twin Lake indicate a prey base dominated by bluegill, with lower densities of topminnows and *Gambusia* present. Analysis of food habits of minnow reared tiger muskellunge in Paris-Twin Lake showed bluegill to be the only identified prey eaten, but numbers of fish with food was low (Table 14). Bluegill have been found to be a sub-optimal forage for tiger muskellunge in previous reservoir studies (Wahl and Stein 1988), and may have contributed to the low survival and growth rates in this lake.

Growth and food habits were also examined for minnow and pellet reared muskellunge in Pierce Lake. Length of minnow reared muskellunge was slightly higher than pellet reared fish. Differences were observed through Week 11, although weight gain was similar by Week 21 (Table 15). Prey consumption was slightly higher for minnow than pellet reared fish (Table 16). No differences were apparent in species consumed between the two rearing types, but sample sizes of minnow and pellet reared fish were low for these comparisons. Brook silversides were the dominant prey item eaten, although a variety of other prey species were also utilized. Cyprinids, gizzard shad, and centrarchids were also important in the diets of muskellunge. Seine hauls in Pierce Lake have shown large numbers of the same species as those found in muskellunge stomachs.

RECOMMENDATIONS: All esocids stocked in 1990 and 1991 should continue to be sampled by electrofishing at monthly intervals to monitor growth and food habits. Seine collections will also continue on all four study lakes in 1992 to evaluate composition, density, and size distribution of available prey. In 1992, we will also monitor growth and food habits of all tiger muskellunge and muskellunge stocked in Jobs 101.1 and 101.2.

JOB 101.5. Assessment of different genetic stocks of muskellunge.

OBJECTIVE: To identify different genetic stocks of muskellunge and to evaluate their performance characteristics for stocking in Illinois impoundments.

INTRODUCTION: Different stocks of muskellunge have evolved under different ecological conditions, and as a result have acquired different performance characteristics. Growth rates, maximum size, longevity, and survival are among the traits that will affect an individual stock's value to Illinois fisheries. Preliminary work has shown that genetic techniques will be useful for identification of geographically distinct stocks. The purpose of this job is to use genetic techniques to identify different genetic stocks of muskellunge and then to evaluate their performance characteristics for stocking in Illinois impoundments. Several molecular techniques are being evaluated for their ability to detect genetic variation in this species. During this segment of the study, we began laboratory evaluations of performance characteristics of the muskellunge populations identified through our genetic work. We compared consumption, growth, and metabolic rates of these populations as a function of water temperature to examine how each population might survive and grow in the thermal regimes present in Illinois.

METHODS AND RESULTS:

Food consumption and growth

Experiments were completed examining temperature effects on food consumption and growth of four muskellunge stocks from Minnesota, New York, Ohio, and Wisconsin. Test temperatures included 5, 10, 15, 25, and 27.5°C and experiments were completed in appropriate seasons to correspond to environmental water temperatures. We tested stocks in a recirculating system that allowed separation of fish into individual aquaria (35 L) while maintaining both constant temperatures and water quality. Ten muskellunge per stock were used for a total of 40 fish per temperature.

Two weeks prior to consumption experiments, muskellunge were randomly assigned to aquaria and acclimated to test temperatures. Muskellunge were starved from one to three days depending on temperature to empty stomach contents and were then measured in weight (g) and length (mm). Muskellunge were fed fathead minnows ad libitum, and wet weights of minnows fed to each fish were recorded to determine 24 hour consumption rates. Experiments lasted two weeks, after which muskellunge were again starved and measured to determine growth.

We compared food consumption (g food consumed/g fish/d) and relative growth (growth/g fish/d) among muskellunge stocks and temperatures. Food consumption (Fig 5) and relative growth (Fig 6) both increased with temperature for all stocks, reaching a peak at 25° C, but declining at 27.5°C.

As expected, differences among temperatures existed in food consumption (ANOVA, Tukey's multiple comparisons, $P<0.0001$) and relative growth (ANOVA, Tukey's multiple comparisons, $P<0.0001$). Within temperatures, we saw no differences in food consumption and relative growth among stocks at the two lowest temperatures (5°C and 10°C). At higher temperatures, the Wisconsin and Ohio stocks had higher consumption and faster growth rates than either

New York or Minnesota.

Metabolic rate experiments

Tests of resting metabolic rate were completed on fingerling muskellunge from five states (Kentucky, Minnesota, New York, Ohio, and Wisconsin) representing four possibly distinct genetic populations (Chautauqua population - NY, Leech Lake population - MN; Ohio population - KY, NY, OH; and Wisconsin population - WI). Fish were hauled or shipped from hatcheries in these five states to the Kaskaskia Biological station in July and August. Fish were held in fiberglass stream tanks and acclimated to test temperatures for two weeks prior to each set of experiments.

Metabolic rate tests were conducted in an environmental chamber which allowed for control of temperature and photoperiod. Initial tests involved evaluation of resting metabolic rate at four temperatures (5°C, 10°C, 15°C, and 25°C). Photoperiod was held constant at 14 h daylight and 10 h dark at 25°C, and 12 h:12 h at each of the other three temperatures. Three to six fish from each stock were tested at each temperature; two to three replicate tests were performed on each fish.

Static as opposed to flow-through chambers were used to measure metabolic rate (Bevelhimer et al. 1985). Measurements were made by sealing each fish in a glass bowl (2.3 l) covered by a plexiglass lid fitted with a polarographic dissolved oxygen probe. Chambers were filled from an aerated head tank and flushed of waste products before and after each test. Fish were starved for 1-3 days prior to each test (depending on temperature), and were transferred to static tests chambers the day before tests were conducted. Once a fish was sealed inside the test chamber, records of oxygen levels inside the chamber were output to a computer at 30 sec intervals. Tests were designed to measure resting metabolic rate, and records of oxygen levels during the tests were also used as a measure of activity. Muskellunge were anesthetized, weighed, and measured at the end of each set of tests. Four to six blanks were run at each temperature to correct for any oxygen demand of the system other than from the fish.

Metabolic rate was calculated as the drop in dissolved oxygen content of the water during the test multiplied by the volume of the test chamber. Values were expressed as a function of the weight of the fish (g) and time (h). Tests lasted for 0.75 h to 1.5 h.

Metabolic rate of fish from these four stocks ranged between 0.05 and 0.1 mg O_2/g/h at 5°C and peaked near 0.25 mg O_2/g/h at 25°C (Table 17). These values are similar to those reported previously for Ohio fish (Bevelhimer et al. 1985), though slightly lower at 5°C and slightly higher at 15°C and 25°C.

Preliminary analysis of data from all tests completed thus far showed little difference in metabolic rate among stocks (Table 17). There were no significant differences in metabolic rate among stocks at 5°C, 15°C, or 25°C. At 10°C some differences were apparent, but were most likely related to differences in weight. For example, at 15°C Kentucky fish were significantly heavier than fish from other populations.

In natural populations, we might expect that Minnesota and Wisconsin fish would consume less oxygen at lower temperatures than fish adapted to warmer temperature regimes. Conversely, Ohio fish might consume less oxygen at higher temperatures. Although there was a positive relationship between temperature and metabolic rate for all muskellunge populations (Table 18), no consistent patterns with temperature were apparent among populations.

Protein electrophoresis

Muskellunge samples received from several state agencies in 1990 and 1991 were analyzed using starch gel electrophoresis. Samples obtained in 1990 have been subject to starch gel electrophoresis to measure genetic variation at loci known to exhibit polymorphism in muskellunge (Table 19). Results of the allozyme analyses were qualitatively similar to those obtained in a preliminary study conducted by Koppelman and Philipp (1986). 6-PGDH was polymorphic in all populations. Two loci, GPI-B and LDH-C, show evidence of geographic differences in allele frequencies. Populations obtained from Minnesota were fixed for one allele at each of these loci. A rare allele at the XDH-1 locus was found in the Spirit Lake, Iowa and Little Falls, Minnesota samples. Rare alleles detected at the EST-1, EST-2, and IDHP-2 loci in the preliminary study (Koppelman and Philipp

1986) were not found in the current study; however, we have not yet evaluated fish from the St. Lawrence R., in which the rare alleles were prevalent.

Allozymes detected by analyzing fin tissue were found to be useful as genetic tags to determine experimental treatment groups. The Gpi-B locus is polymorphic and easily detected in fin tissue, and may also be useful for producing genetically tagged stocks for performance evaluations in Illinois.

RFLP Analysis of Mitochondrial DNA

Mitochondrial DNA (mtDNA) is also useful for measuring genetic variability. Much current mtDNA work with gamefish utilizes liver tissue to isolate large quantities of mtDNA, the RFLP products of which are visualized with ethidium bromide staining. However, because adult muskellunge are such a valuable resource, it is not desirable to use destructive sampling techniques commonly used to evaluate mtDNA RFLP's. Unfortunately, DNA isolation procedures using fin clips have not yielded ample quantities of intact mtDNA for RFLP analysis, even using radioactively-labelled DNA probe techniques.

RAPD Analysis of Genomic DNA

To develop another molecular technique capable of detecting genetic variation using non-destructive sampling procedures, we have adapted a new procedure for use with fish. This procedure uses random-sequence 10-base primers in a PCR reaction to generate a series of DNA fragments of different sizes and numbers. These fragments are then separated electrophoretically on an agarose gel and visualized through staining with ethidium bromide. These banding patterns show mutational variation among individuals and thereby allow genetic comparisons. We have developed specific conditions for analyzing muskellunge using this technique and have assessed a number of primers for variation among several individuals from four populations. The amount of variation generated by this technique is extensive and will prove quite valuable for describing various stocks of muskellunge and other sportfish.

RECOMMENDATIONS: Fish from all of the current sources, plus St. Lawrence River fish have been obtained for laboratory tests during the coming year. These fish will allow us to increase sample sizes and examine differences in growth, consumption, and metabolic rates among muskellunge from the different populations. Additional data analysis will include examination of activity effects on metabolic rate, allowing extrapolation to a true resting rate. Final development of a flow-through testing system will allow us to determine metabolic rate more quickly. Future work on performance characteristics should involve continued work in the laboratory on those muskellunge stocks already examined plus some additional populations. Thus far our work on performance evaluation has emphasized differences among young-of-year fish. Future work should begin to address differences among stocks of larger fish. Work on these fish will help determine which muskellunge stocks are best suited for stocking in Illinois. Parameters including temperature tolerance (preferred and lethal), growth rates (time to reach trophy size, maximum final size, size at first reproduction), distribution of energy intake to reproductive versus somatic growth, and longevity/survival need to be evaluated in pond and / or field studies. Knowledge concerning all of these traits will help to better define individual populations and their potential value to Illinois fisheries.

RAPD analysis of genomic DNA should be extended to much larger samples. Approximately 20-30 individuals from a number of different populations should be analyzed. In addition, various non-lethal sampling procedures (e.g. blood, muscle plugs, and fin clips should be assessed for use in RAPD analysis).

JOB 101.6. <u>**Analysis and reporting.**</u>

OBJECTIVE: To prepare annual and final reports which develop management guidelines for stocking esocids in Illinois impoundments.

RESULTS AND RECOMMENDATIONS: Relevant data were analyzed and reported in individual jobs of this report (see Job 101.1-101.5).

References:

Bevelhimer, M. S., R. A. Stein, and R. F. Carline. 1985. Assessing significance of physiological differences among three esocids with a bioenergetics model. Canadian Journal of Fisheries and Aquatic Sciences 42:57-69.

Carline, R.F., R.A. Stein, L.M. Riley. 1986. Effects of size at stocking, season, largemouth bass predation, and forage abundance on survival of tiger muskellunge. Am. Fish. Soc. Spec. Publ. 15:151-167.

Foster, J.R. 1977. Pulsed gastric lavage: an efficient method of removing the stomach contents of live fish. Prog. Fish-Culturist 39:166-169.

Gillen, A.L., R.A. Stein and R.F. Carline. 1981. Predation by pellet-reared tiger muskellunge on minnows and bluegills in experimental systems. Trans. Am. Fish Soc. 110:197-209.

Hanson, D.A., M.D. Staggs, S.L. Serns, L.D. Johnson, and L.M. Andrews. 1986. Survival of stocked muskellunge eggs, fry, and fingerlings in Wisconsin lakes. Am. Fish. Soc. Spec. Publ. 15:216-228.

Johnson, L.D. 1978. Evaluation of esocid stocking program in Wisconsin. Am. Fish. Soc. Spec. Pub. 11:298-301.

Klingbiel, J.H. 1986. Culture of purebred muskellunge. In: Hall, G.E. (ed). Managing Muskies. Am. Fish. Soc. Spec. Pub. 15:273-278.

Keith, W.E. 1986. A review of introduction and maintenance stocking in reservoir fisheries management. In: G.E. Hall and M.J. Van Den Avyle (eds). Reservoir fisheries management: strategies for the 80's. Res. Comm., South. Div. Am. Fish. Soc.:144-148.

Koppelman, J.B. and D.P. Philipp. 1986. Genetic applications in muskellunge management. Trans. Am. Fish. Soc. Spec. Publ. 15:111-121.

Mather, M.E. and D.H. Wahl 1989. Comparative mortality of three esocids due to stocking stressors. Can. J. Fish. Aquat. Sci. 46:214-217.

McNeil, F.I. and E.J. Crossman. 1979. Fin clips in the evaluation of stocking programs for muskellunge (*Esox masquinongy*). Trans. Am. Fish. Soc. 108(4):335-343.

Savino, J.F. and R.A. Stein. 1982. Predator-prey interaction between largemouth bass and bluegills as influenced by simulated, submersed vegetation. Trans. Am. Fish. Soc. 111:255-266.

Stein, R.A., R.F. Carline, and R.S. Hayward. 1981. Largemouth bass predation on stocked tiger muskellunge. Trans. Am. Fish. Soc. 110:604-612.

Tomcko, C.M., R.A. Stein, and R.F. Carline. 1984. Predation by tiger muskellunge on bluegill: effects of predator experience, vegetation, and prey density. Trans. Am. Fish. Soc. 113:588-594.

Van Den Avyle, M.J. and J.E. Roussel. 1980. Evaluation of a simple method for removing food items from live black bass. Progressive Fish-Culturist 42:222-223.

Wahl, D.H. and R.A. Stein 1987. Application of liquid oxytetracycline in formulated feeds to mark and treat tiger muskellunge (muskellunge x northern pike). Prog. Fish. Cult. 49:312-314.

Wahl, D.H. and R.A. Stein. 1988. Selective predation by three esocids: the role of prey behavior and morphology. Trans. Am. Fish. Soc. 117:142-151.

Wahl, D.H. and R.A. Stein 1989. Comparative vulnerability of three esocids to largemouth bass (Micropterus salmoides) predation. Can. J. Fish. Aquat. Sci. 46:2095-2103.

Wahl, D.H. and R.A. Stein. 1990. Food consumption and growth by three esocids: field tests of a bioenergetics model. Trans. Am. Fish. Soc. 120:230-246.

Werner, E.E., J.F. Gilliam, D.J. Hall and G.G. Mittelbach. 1983. An experimental test of the effects of predation risk on habitat use in fish. Ecology. 64(6):1540-1548.

Table 1. Summary of all esocid stockings in four Illinois impoundments in 1991-92. Total length (nearest mm) and weight (nearest 0.1 g) were measured prior to each stocking (N=50). Paris-Twin and Pierce lakes were stocked with both pellet reared (P) and minnow reared (M) fish. Lakes were stocked with tiger muskellunge (TM) or muskellunge (MU).

Lake		Taxa	Stocking Date	Number of Fish	Number per Hectare	Mean Length (mm)	Mean Weight (g)
Paris	(M)	TM	Jul 16	1700	26	202	36.7
	(P)	TM	Jul 16	1700	26	201	34.4
Pierce	(M)	MU	Jan 27	398	6	205	37.4
	(P)	MU	Jan 27	398	6	195	25.9
Paradise		TM	May 20	2070	29	93	3.9
		TM	Jul 8	1490	21	191	32.3
		TM	Jan 28	1457	20	283	107.6
George		MU	Jul 24	1375	20	98	3.6
		MU	Sep 5	760	11	265	97.4
		MU	Sep 11	900	15	218	43.0

Table 2. Schnabel population estimates and relative survival through fall 1991 of stocked esocids determined by electrofishing mark-recapture estimates. Values for Pierce Lake and for 10 inch tiger muskellunge in Paradise Lake represent spring estimates from 1992. (M) designates minnow reared and (P) designates pellet reared esocids. Values in parenthesis represent total catch.

		Population Estimate		
Lake	Taxa	Point Estimate	95% C.I.	% Survival
Paris-Twin	TM (M)	(1)	--	0
	TM (P)	0	--	0
Pierce	MU (M)	183	153-220	46
	MU (P)	98	68-147	24
Paradise	TM (4 in)	0	--	0
	TM (8 in)	(6)	--	0
	TM (10 in)	391	190-977	27
George	MU (4 in)	0	--	0
	MU (8 in)	13	7-30	1
	MU (10 in)	21	12-40	3

Table 3. Catch-per-unit-effort (CPUE) from electrofishing on successive days after stocking for 4, 8 and 10 inch tiger muskellunge in Paradise Lake, 1991-2. Data are midpoints of one or more sample collections.

Date	Effort (hrs)	Catch (c)			CPUE (c/hr)		
		4 in	8 in	10 in	4 in	8 in	10 in
May 20	1.78	25	-	-	14.0	-	-
May 21	1.83	2	-	-	1.1	-	-
May 22	1.45	1	-	-	0.7	-	-
Jul 8	2.05	0	76	0	0	37.1	-
Jul 9	1.95	0	16	0	0	8.2	-
Jul 10	1.72	0	7	0	0	4.0	-
Jul 23	3.57	0	15	0	0	4.2	-
Oct 2	2.75	0	2	0	0	0.7	-
Oct 27	4.04	0	1	0	0	0.2	-
Nov 9	3.16	0	4	0	0	1.3	-
Feb 5	1.90	0	0	25	0	0	13.2
Mar 1	3.05	0	0	36	0	0	11.8
Mar 20	3.66	0	0	16	0	0	4.4
Mar 29	3.25	0	0	16	0	0	4.9
Apr 9	3.50	0	0	14	0	0	4.0

Table 4. Catch-per-unit-effort (CPUE) from electrofishing on successive days after stocking for 4, 8 and 10 inch muskellunge in Lake George, 1991-2. Data are midpoints of one or more sample collections.

Date	Effort (hrs)	Catch (c)			CPUE (c/hr)		
		4 in	8 in	10 in	4 in	8 in	10 in
Jul 25	2.30	27	-	-	11.7	-	-
Jul 26	2.25	4	-	-	1.8	-	-
Jul 29	2.13	1	-	-	0.4	-	-
Sep 6	2.33	0	-	56	0	-	24.0
Sep 9	2.20	0	-	20	0	-	9.1
Sep 15	5.30	0	16	8	0	3.0	1.5
Oct 9	6.00	0	12	13	0	2.0	2.2
Oct 15	2.36	0	2	6	0	0.8	2.5
Oct 30	2.00	0	2	2	0	1.0	1.0
Nov 15	3.30	0	4	2	0	1.2	0.6
Mar 17	6.01	0	8	15	0	1.3	2.5
Mar 27	5.92	0	8	8	0	1.4	1.4
Apr 8	4.72	0	4	7	0	0.8	1.5

Table 5. Schnabel population estimates of largemouth bass determined by mark-recapture in three impoundments stocked with muskellunge and tiger muskellunge, 1991. Minimum sizes of largemouth bass used in population estimates are based on maximum prey/predator ratios observed for esocids recovered from bass stomachs. In Lake George, separate estimates represent estimates for stockings of 4 and 10 inch muskellunge.

Lake	Taxa	Minimum size	Population Estimate	
			Point Estimate	95% C.I.
Paris-Twin	LMB	270	398	241-710
Paradise	LMB	135	567	450-713
George	LMB	135	816	619-1103
	LMB	355	153	100-251

Table 6. Estimated numbers of esocids eaten by largemouth bass in two impoundments with tiger muskellunge (TM) and one impoundment with muskellunge (MU). Paris Lake was stocked with minnow (M) and pellet (P) reared fish. Values were computed by combining number of esocids per largemouth bass stomach with largemouth bass population estimates. No 8 inch tiger muskellunge (Paradise Lake) or 8 inch muskellunge (Lake George) were recovered from largemouth bass stomachs. Bass predation on 10 inch tiger muskellunge (Paradise Lake) and minnow and pellet reared muskellunge (Pierce Lake) could not be estimated due to winter stocking.

Lake	Taxa	Number eaten	Number stocked	Percent of total
Paradise	TM	145 (4")	2070	7.0
George	MU	1361 (4")	1375	99.0
	MU	5 (10")	760	0.7
Paris	TM	1200 (P)	1700	70.6
	TM	271 (M)	1700	15.9

Table 7. Catch-per-unit-effort (CPUE) from electrofishing on successive days after stocking for minnow (M) and pellet (P) reared tiger muskellunge in Paris-Twin Lake, 1991. Data are midpoints of one or more sample collections.

Date	Effort (hrs)	Catch (c)		CPUE (c/hr)	
		M	P	M	P
Jul 17	2.03	49	5	24.1	2.4
Jul 18	2.66	20	0	7.5	0
Jul 22	3.66	6	1	1.6	0.3
Jul 29	3.41	21	20	6.1	5.9
Aug 5	2.80	3	10	1.1	3.5
Aug 20	3.58	5	1	1.4	0.3
Sep 26	2.75	1	0	0.3	0
Oct 18	1.66	0	0	0	0

Table 8. Catch-per-unit-effort from electrofishing on successive days after stocking for minnow (M) and pellet (P) reared muskellunge in Pierce Lake, 1992. Data are midpoints of one or more sample collections.

Date	Effort (hrs)	Catch (c)		CPUE (c/hr)	
		M	P	M	P
Mar 17	2.83	61	26	21.6	9.2
Mar 18	2.30	41	20	17.8	8.7
Mar 19	2.17	44	15	20.3	6.9
Mar 26	3.88	78	21	20.1	5.4
Apr 5	4.25	40	6	9.4	1.4
Apr 22	5.96	5	1	0.8	0.1
May 25	6.24	2	0	0.3	0
Jun 16	5.03	3	0	0.6	0

Table 9. Average lengths and weights after stocking of 8 and 10 inch muskellunge in Paradise Lake from fall and spring electrofishing samples. Dashes indicate periods when no fish were collected or no data was available.

	8 inch			10 inch		
Week	Length (mm)	Weight (g)	N	Length (mm)	Weight (g)	N
3	192.6	27.6	16	-	-	-
6	-	-	-	288.1	104.2	36
9	196.0	34.0	1	285.7	93.6	26
11	-	-	-	290.5	103.2	20
20	310.3	161.0	4	-	-	-
35	336.0	186.0	1	-	-	-

Table 10. Monthly food habits of 8 and 10 inch tiger muskellunge in Paradise Lake collected from fall and spring electrofishing samples.

Date	% with food	N	Prey species composition: Gizzard shad	*Lepomis* spp	Unidentified
			8 inch		
July/Aug	12	16	1	1	0
Oct/Nov	67	6	3	0	0
			10 inch		
Feb	24	42	9	0	1
Mar	33	52	16	0	1
Apr	50	14	7	0	0

Table 11. Average lengths and weights after stocking of 8 and 10 inch muskellunge in Lake George from fall and spring electrofishing samples. Dashes indicate periods when no fish were collected or no data was available.

	8 inch			10 inch		
Week	Length (mm)	Weight (g)	N	Length (mm)	Weight (g)	N
3	-	-	-	271.4	96.4	28
6	238.5	57.1	14	286.5	104.4	19
10	259.7	72.0	6	323.3	134.0	4
28	266.0	76.3	13	323.2	156.6	19
31	265.6	82.3	7	318.6	145.6	11

Table 12. Monthly food habits of 8 and 10 inch muskellunge in Lake George collected from fall and spring electrofishing samples.

			Prey species composition			
Date	% with food	N	Cyprinid spp.	*Lepomis* spp.	Largemouth Bass	Unknown
			8 inch			
Sep	6	16	1	0	0	0
Oct/Nov	37	8	1	1	0	1
Mar/Apr	22	18	2	1	0	1
			10 inch			
Sep	4	45	0	0	0	1
Oct/Nov	9	11	0	0	0	1
Mar/Apr	33	24	1	3	1	5

Table 13. Average lengths and weights after stocking of minnow and pellet reared tiger muskellunge in Paris-Twin Lake from fall electrofishing samples. Dashes indicate periods when no fish were collected.

	Minnow			Pellet		
Week	Length (mm)	Weight (g)	N	Length (mm)	Weight (g)	N
2	197.5	31.5	6	197.0	27.0	1
3	211.5	34.8	21	210.0	33.8	19
5	215.1	35.5	8	211.6	33.5	11
7	245.0	60.0	1	-	-	-

Table 14. Monthly food habits of minnow and pellet reared tiger muskellunge in Paris-Twin Lake collected from fall electrofishing samples.

Date	Minnow		Pellet		Prey species	
	% with food	N	% with food	N	*Lepomis* spp.	Unknown
Jul	11	27	0	21	3	0
Aug/Sep	12	16	0	4	1	1

Table 15. Average lengths and weights after stocking of minnow and pellet reared muskellunge in Pierce Lake from spring electrofishing samples. Dashes indicate periods when no fish were collected.

	Minnow			Pellet		
Week	Length (mm)	Weight (g)	N	Length (mm)	Weight (g)	N
9	208.5	34.7	75	192.1	22.4	20
10	214.8	38.3	29	199.5	25.5	4
12	214.4	37.0	12	189.7	18.7	3
16	232.8	52.0	4	-	-	-
21	259.0	79.3	3	-	-	-

Table 16. Monthly food habits of minnow and pellet reared muskellunge in Pierce Lake collected from spring electrofishing samples.

	Minnow		Pellet		Prey species composition				
Date	% with food	N	% with food	N	Brook Silverside	Cyprinid spp.	*Lepomis* spp.	Gizzard shad	Unknown
Mar	12	224	9	82	11	7	5	0	11
Apr	14	43	0	7	4	0	0	1	2
Jun	100	3	-	-	2	1	0	0	0

Table 17. Metabolic rate (mg $O_2 \times g^{-1} \times h^{-1}$) of five muskellunge stocks at four temperatures. Two to three replicate tests were performed on each fish (N) tested. Values in parentheses are one standard deviation.

Stock	Temperature	N	Weight (g)	Metabolic Rate
Kentucky	5	3	17.82 (0.95)	0.072 (0.032)
	10	6	20.20 (5.77)	0.118 (0.030)
	15	4	28.02 (1.61)	0.135 (0.030)
	25	3	19.89 (0.77)	0.216 (0.040)
Minnesota	5	5	12.95 (1.56)	0.075 (0.029)
	10	5	14.05 (2.31)	0.208 (0.030)
	15	6	13.48 (1.00)	0.222 (0.018)
	25	6	14.84 (2.25)	0.251 (0.034)
New York	5	5	13.44 (1.03)	0.076 (0.036)
	10	5	15.71 (1.57)	0.155 (0.043)
	15	8	14.18 (2.86)	0.195 (0.031)
	25	6	13.74 (2.66)	0.253 (0.057)
Ohio	5	5	17.24 (1.75)	0.088 (0.029)
	10	5	18.13 (1.98)	0.131 (0.040)
	15	5	14.89 (2.20)	0.222 (0.027)
	25	6	13.94 (2.54)	0.253 (0.046)
Wisconsin	5	4	17.14 (1.40)	0.097 (0.028)
	10	4	16.35 (0.90)	0.188 (0.038)
	15	6	14.26 (1.73)	0.226 (0.044)
	25	6	14.82 (1.36)	0.237 (0.046)

Table 18. Relationship between temperature (T) and metabolic rate (RATE) for five muskellunge stocks.

Stock	Equation	R^2	P
KY	RATE=(0.006*T)+0.048	0.70	0.0001
MN	RATE=(0.008*T)+0.086	0.65	0.0001
NY	RATE=(0.008*T)+0.059	0.70	0.0001
OH	RATE=(0.008*T)+0.059	0.76	0.0001
WI	RATE=(0.006*T)+0.006	0.53	0.0002

Table 19. Allele frequencies of muskellunge at polymorphic loci.

	Loci						
Location	LDH-C	IDHP-2	6-PGDH-1	XDH-1	GPI-B	EST-1	EST-2
Chautaqua, NY	1- .600 2- .400	1- 1.000 2- .000	1- .375 2- .625	1- 1.000 2- .000	1- .725 2- .275	1- .000 2- 1.000	1- 1.000 2- .000
Lineville, PA	1- .675 2- .325	1- 1.000 2- .000	1- .825 2- .125	1- 1.000 2- .000	1- .800 2- .200	1- .000 2- 1.000	1- 1.000 2- .000
Union City, PA	1- .475 2- .525	1- 1.000 2- .000	1- .450 2- .550	1- 1.000 2- .000	1- .825 2- .175	1- .000 2- 1.000	1- 1.000 2- .000
Mt. Pleasant, PA	1- .450 2- .550	1- 1.000 2- .000	1- .467 2- .533	1- 1.000 2- .000	1- .800 2- .200	1- .000 2- 1.000	1- 1.000 2- .000
Morehead, KY	1- .000 2-1.000	1- 1.000 2- .000	1- .475 2- .525	1- 1.000 2- .000	1- .975 2- .025	1- .000 2- 1.000	1- 1.000 2- .000
Spirit L., IA	1- .500 2- .500	1- 1.000 2- .000	1- .786 2- .214	1- .867 2- .133	1- .300 2- .700	1- .000 2- 1.000	1- 1.000 2- .000
East Fork Hatchery, IN	1- .175 2- .825	1- 1.000 2- .000	1- .350 2- .650	1- 1.000 2- .000	1- .550 2- .450	1- .000 2- 1.000	1- 1.000 2- .000
Leech L., MN	1- .000 2-1.000	1- 1.000 2- .000	1- .733 2- .267	1- 1.000 2- .000	1- .000 2- 1.000	1- .000 2- 1.000	1- 1.000 2- .000
Waterville, MN	1- .000 2-1.000	1- 1.000 2- .000	1- .867 2- .133	1- 1.000 2- .000	1- .000 2- 1.000	1- .000 2- 1.000	1- 1.000 2- .000
Little Falls, MN	1- .000 2-1.000	1- 1.000 2- .000	1- .875 2- .125	1- .950 2- .050	1- .000 2- 1.000	1- .000 2- 1.000	1- 1.000 2- .000

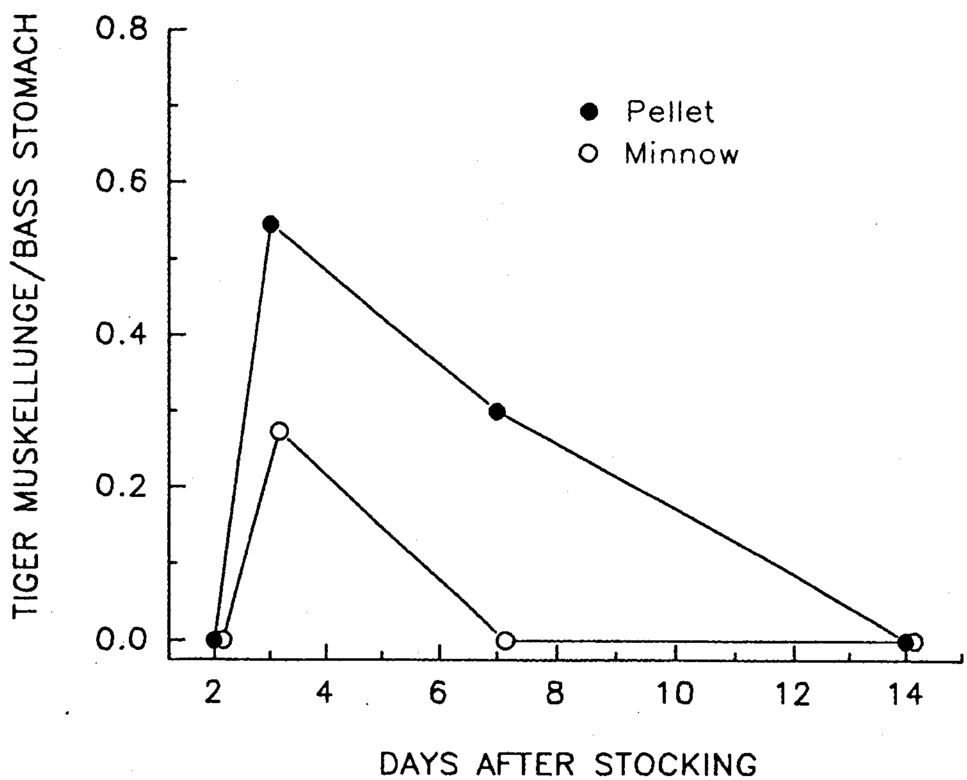


Figure 1. Numbers of tiger muskellunge recovered from largemouth bass stomachs on successive days after stocking in Paris-Twin Lake.

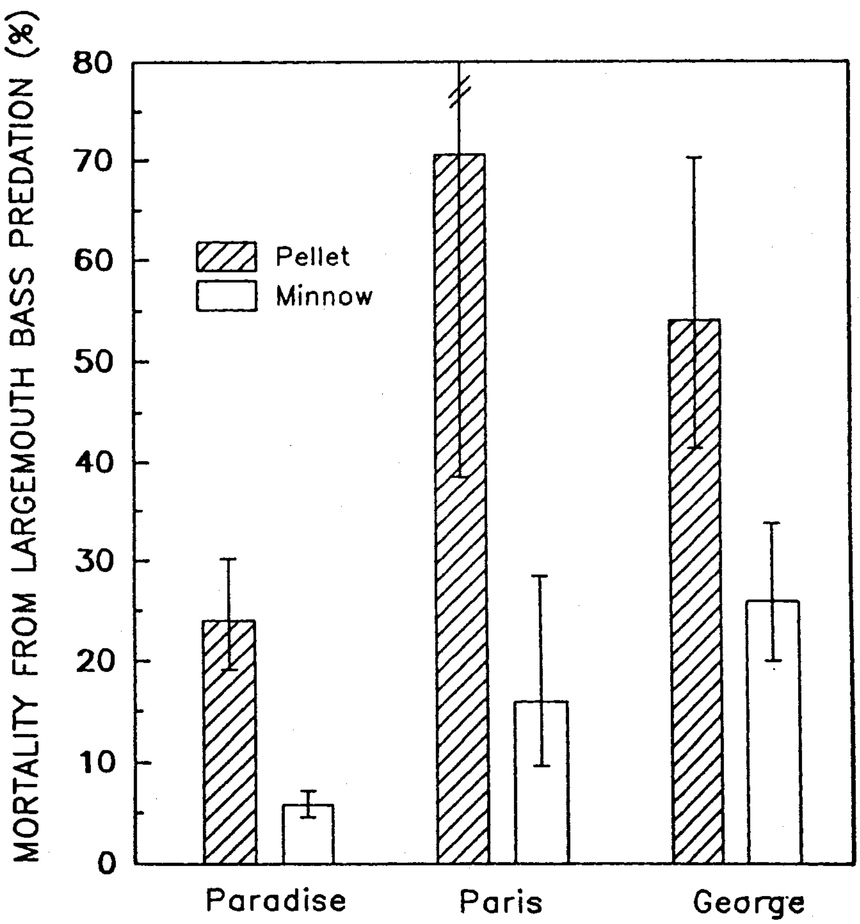


Figure 2. Percent mortality due to largemouth bass predation in two reservoirs stocked with tiger muskellunge (Paradise, Paris) and one reservoir stocked with muskellunge (George).

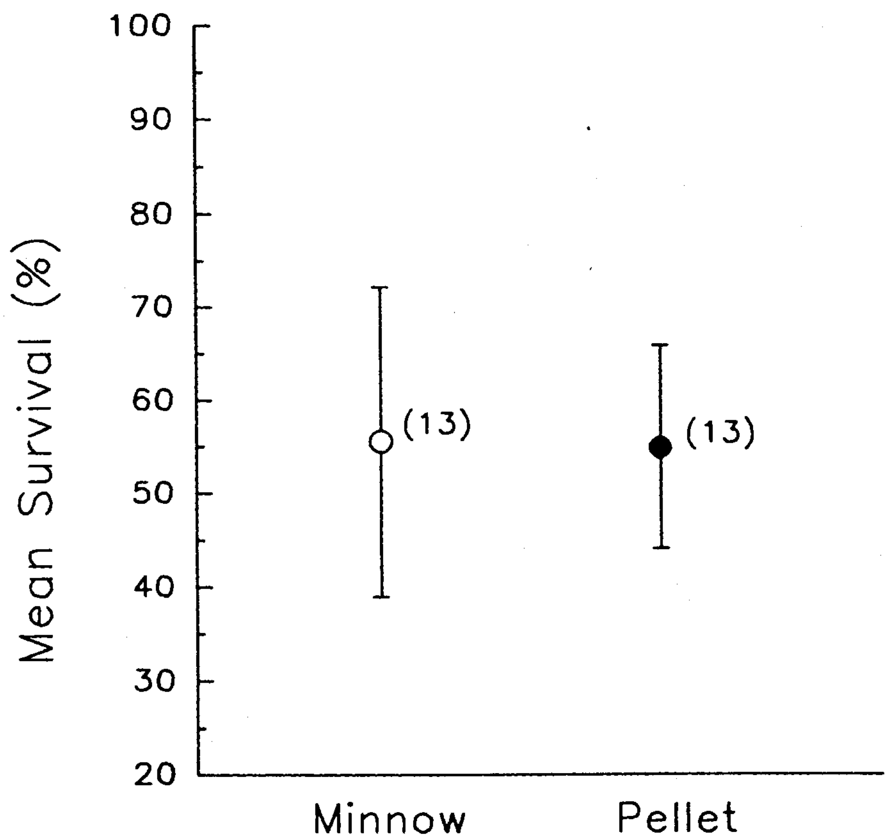


Figure 3. Mean survival of minnow and pellet reared tiger muskellunge in pond experiments during 1990 and 1991. Survival values incorporate natural mortality from control ponds.

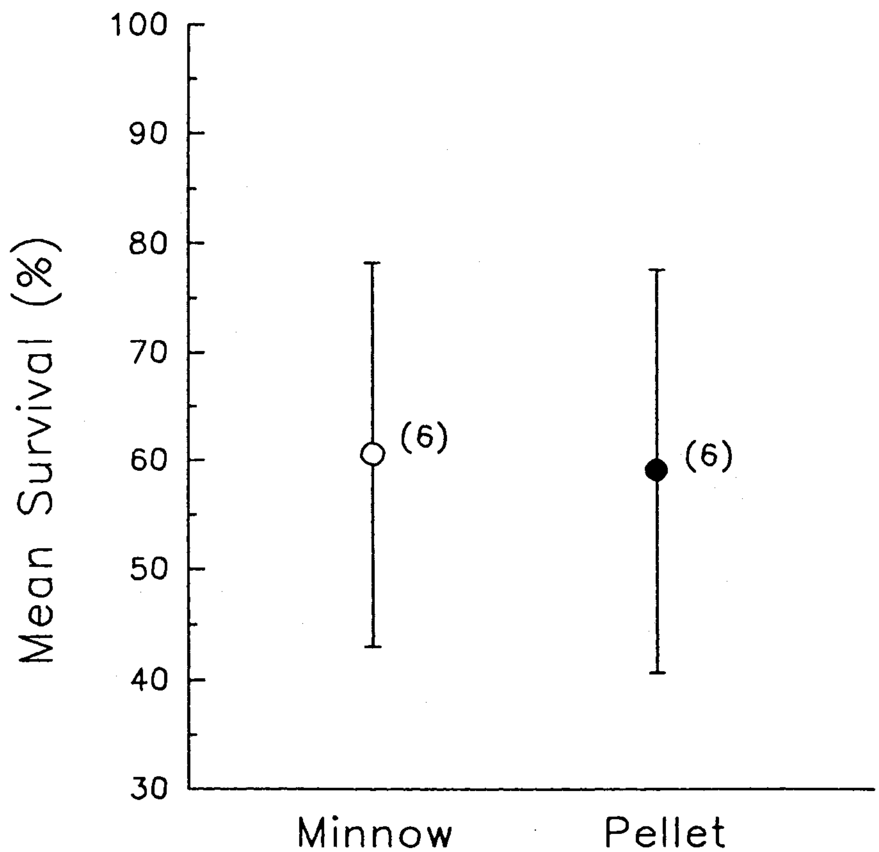


Figure 4. Mean survival of minnow and pellet reared muskellunge in pond experiments during 1990. Survival values incorporate natural mortality from control ponds.

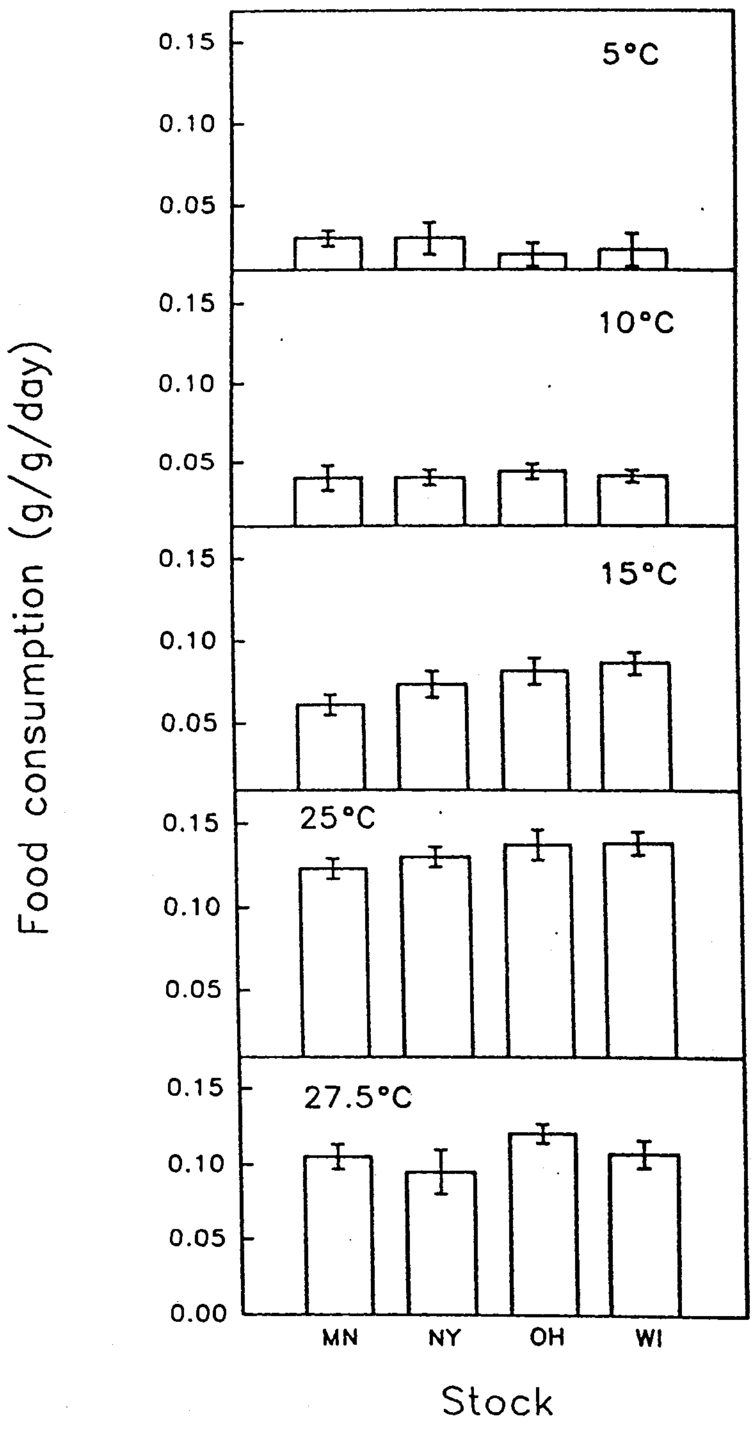


Figure 5. Comparisons of food consumption for four muskellunge stocks at five temperatures. Vertical lines represent 95% confidence intervals.

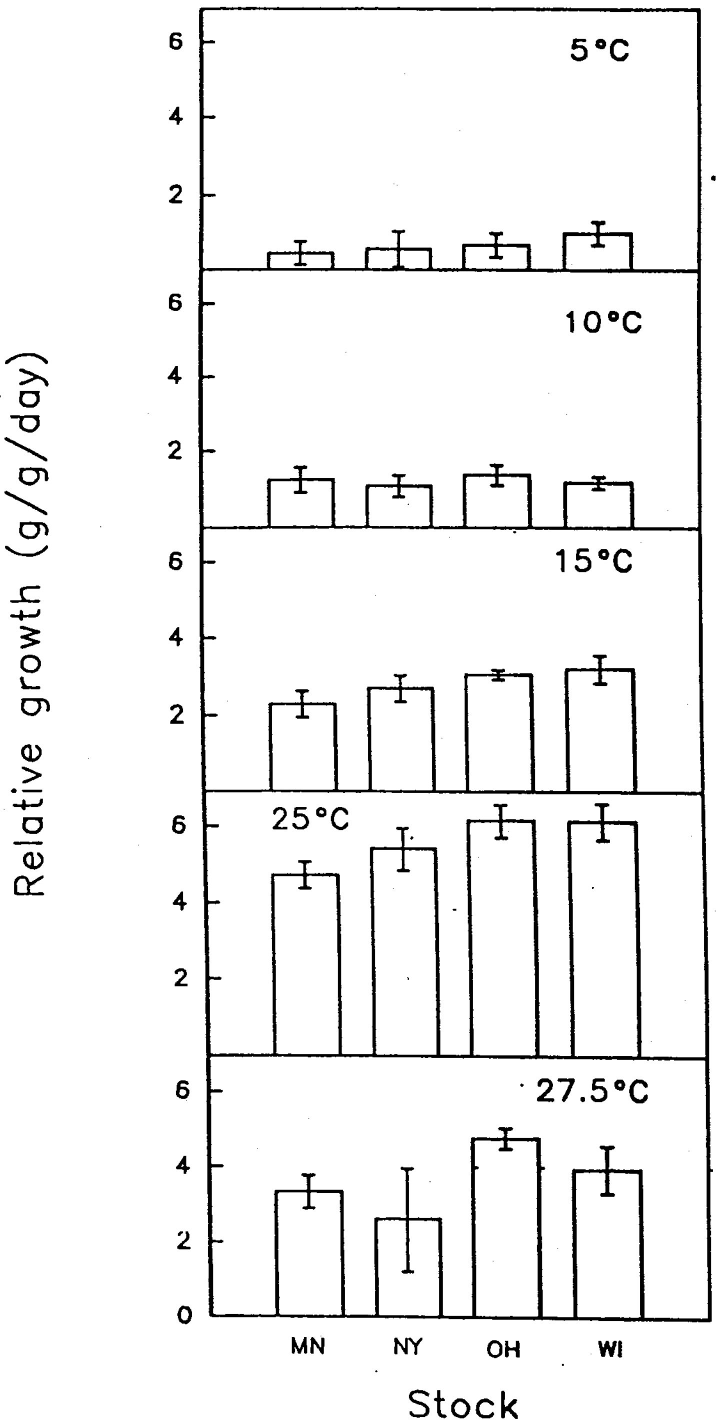


Figure 6. Comparisons of relative growth for four muskellunge stocks at five temperatures. Vertical lines represent 95% confidence intervals.